SECTION II.—GENERAL METEOROLOGY.

THE DUSTFALLS OF MARCH, 1918.

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[Dated: Madison, Wis., Dec. 24, 1918.]

Light falls of dust occur so frequently as to attract no attention, except from housewives; heavier falls are rare and pass away so quickly that quantitative measurements of them are not often made. Unusually heavy dustfalls occurred in March, 1918, in the Central and Eastern States. At Madison the time of beginning and end of the fall and the density of the fall were accurately determined, and the dust has been examined by investigators familiar with the physical, mineralogical, zoological, and botanical problems presented by it. Atmospheric dust has been discussed in its general relations by Free (1) and by Humphreys (3) (4), so that this paper will be confined to the presentation of the data collected relative to the dustfalls of March, 1918.

Origin of the dust.—Notwithstanding the impression of some of the observers of the dustfall, that the dust was of local origin, the following circumstances point to the arid Southwest as the source from which it came:

(*a*) High winds, dust storms, and sand storms occurred from Arizona eastward to the Mississippi River. Part of the area was especially liable to the blowing of soil on account of an unusually prolonged drought.

(*b*) The Northern States, including most of those in which the deposit of dust was observed, were covered with snow, as shown in figures 1 and 3 (shaded areas), where the limits of snow on the ground on March 4 and 11 are reproduced from the Snow and Ice Bulletins of the Weather Bureau.

(*c*) The Southeastern and Central States had no protecting cover of snow, but the wetness of the soil and the cover of vegetation seems to have kept down the blowing of soil. Inquiries addressed to the section directors of the climatological services of Illinois, Indiana, and Ohio brought the response that, while high winds accompanied the March storms, no reports of blowing of soil had come to their notice.

(*d*) Microscopic study of the dust collected at Madison, Wis., and at Oberlin, Ohio, reveals several facts having an important bearing on its origin. First, it is well sorted and very fine. Both of these facts indicate that it has been carried a long distance in the air. Next, the dust contains abundant limonite and hematite, although kaolin is not abundant and the feldspar is entirely unaltered. These facts indicate that the dust is a product of physical disintegration and not of chemical decomposition, therefore that it is derived from a region of very arid climate and not from any part of the Mississippi Valley. Again, the dust is dominantly composed of feldspar and quartz, with very small amounts of other constituents. Therefore it is derived from a region of siliceous feldspathic rocks, either granite or arkose, or a gneiss of similar composition, like the Rocky Mountain region. It is not derived from a region of limestone, sandstone, mica schist, or basic igneous rocks. It con-

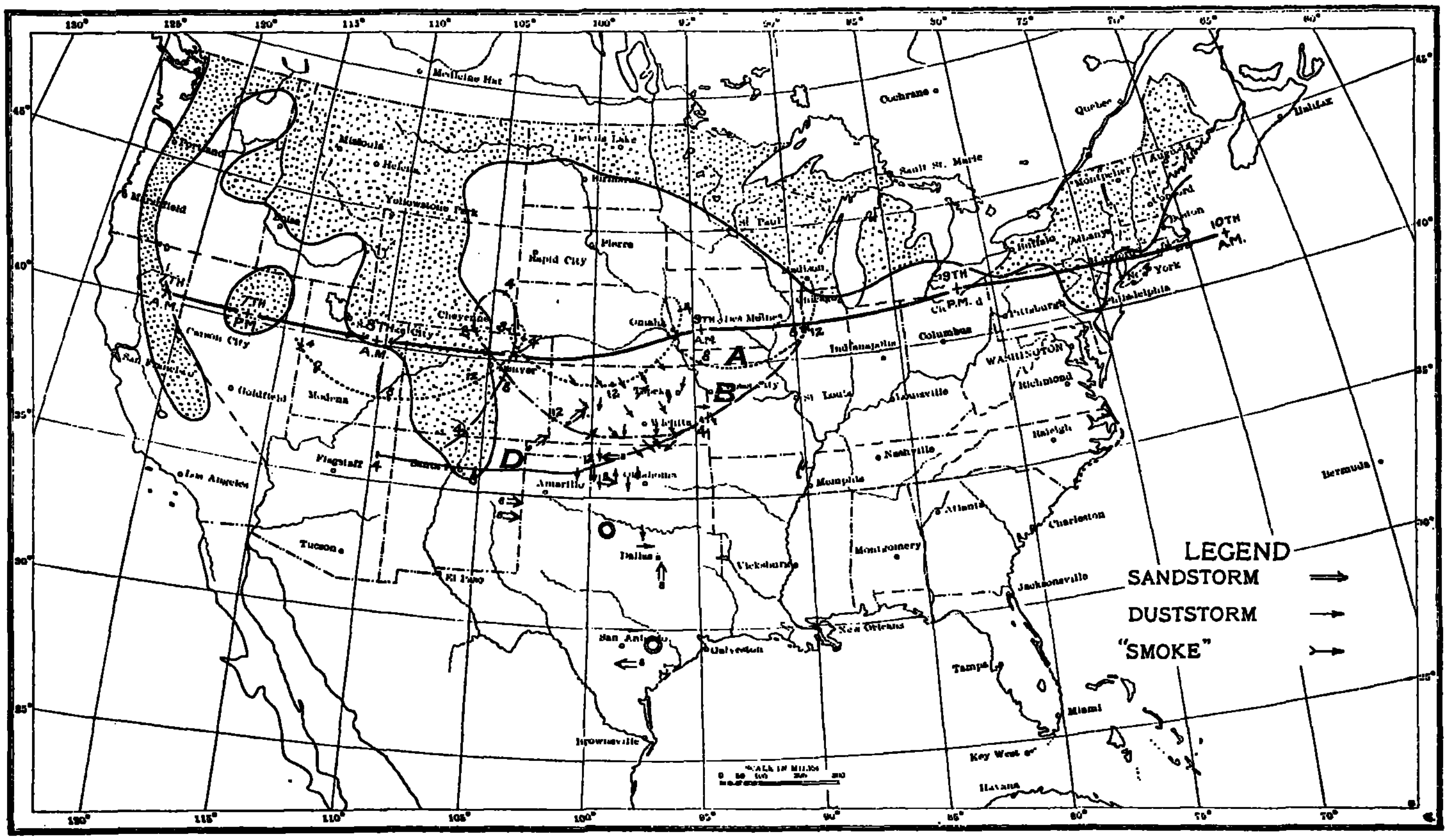

FIG. 1.—Dust of March 8 and 9, 1918: Cyclone track, wind paths, snow-covered area (shaded), 8 p. m., March 4, and dust storms and sand storms reported by cooperative observers of the Weather Bureau in Arizona, New Mexico, Texas, Oklahoma, Kansas, and Missouri on March 8 (marked "8") and March 9, 1918.

tains far too little kaolin, and its feldspar is too fresh to be derived from any ordinary shale or argillite. Therefore it is not derived from any part of the Mississippi Valley east of the Rocky Mountains or south of Minnesota. Finally, the proportion of organic materials in the dust (about 5 per cent) is so much smaller than the proportion reported in European dustfalls as to indicate a barren region as the place of origin.

Translocating agents.—Three well-developed cyclones crossed the continent in March, 1918; the tracks of the centers of these, numbered III, IV, and V, are shown on Chart XLVI-24, "Tracks of centers of low areas, March, 1918," in the MONTHLY WEATHER REVIEW, March, 1918. No. III appeared on the California coast on the evening of the 6th and passed off the field of the weather map in the vicinity of Newfoundland on the morning of the 11th (see fig. 1). No. IV crossed between the morning of the 10th and the night of the 13th (see fig. 2); No. V, between the morning of the 11th and the night of the 15th (see fig. 3). III and V followed nearly the same path eastward from Utah along the parallel of 40° to Lake Erie, thence east-northeast to Newfoundland. IV entered over northern California, but followed a more northerly course.

Cyclone III was characterized by unusually high winds. Of the list of winds of 50 miles per hour or higher tabulated in the MONTHLY WEATHER REVIEW, March, 1918, page 155, nearly one-half were due to this storm. The following table gives the higher velocities, for 5 minutes, attained in successive 12-hour intervals between the simultaneous observations at 8 a. m. and 8 p. m., 75th Meridian Time:

March 7-8, p. m. to a. m., Modena, Utah, 30 miles per hour.
March 8, a. m. to p. m., Modena, 52; Flagstaff, Ariz., 48.
March 8-9, p. m. to a. m., Oklahoma, 48; Denver, 44; Wichita, 44.
March 9, a. m. to p. m., St. Louis, 74; Wichita, 65.
March 9-10, p. m. to a. m., Washington, 40; Pittsburgh, 40.
March 10, a. m. to p. m., New York, 87.

The area of deflation (blowing away of fine dust) in Arizona, New Mexico, Texas, Oklahoma, Kansas, and Missouri, due to storm III is shown in figure 1, and those due to LOWS IV and V in figures 2 and 3. These reports of dust storms and sand storms on March 8, 9, 10, 11, 12, and 13 have been charted for us from the reports of cooperative observers of the Weather Bureau through the kindness of Mr. Herbert Lyman, of the MONTHLY WEATHER REVIEW staff.

Trajectory of the dust cloud.—The advance of a dust cloud has been traced in some of the instances quoted by Free (1), and in the case of the volcanic dust from Katmai by Kimball (6). We have not been able to imitate this procedure, for the reason that we have so far obtained no definite observations of atmospheric haze, except from observers in Ohio on March 12. We have, therefore, tried to conjecture the probable path on the basis of the following considerations:

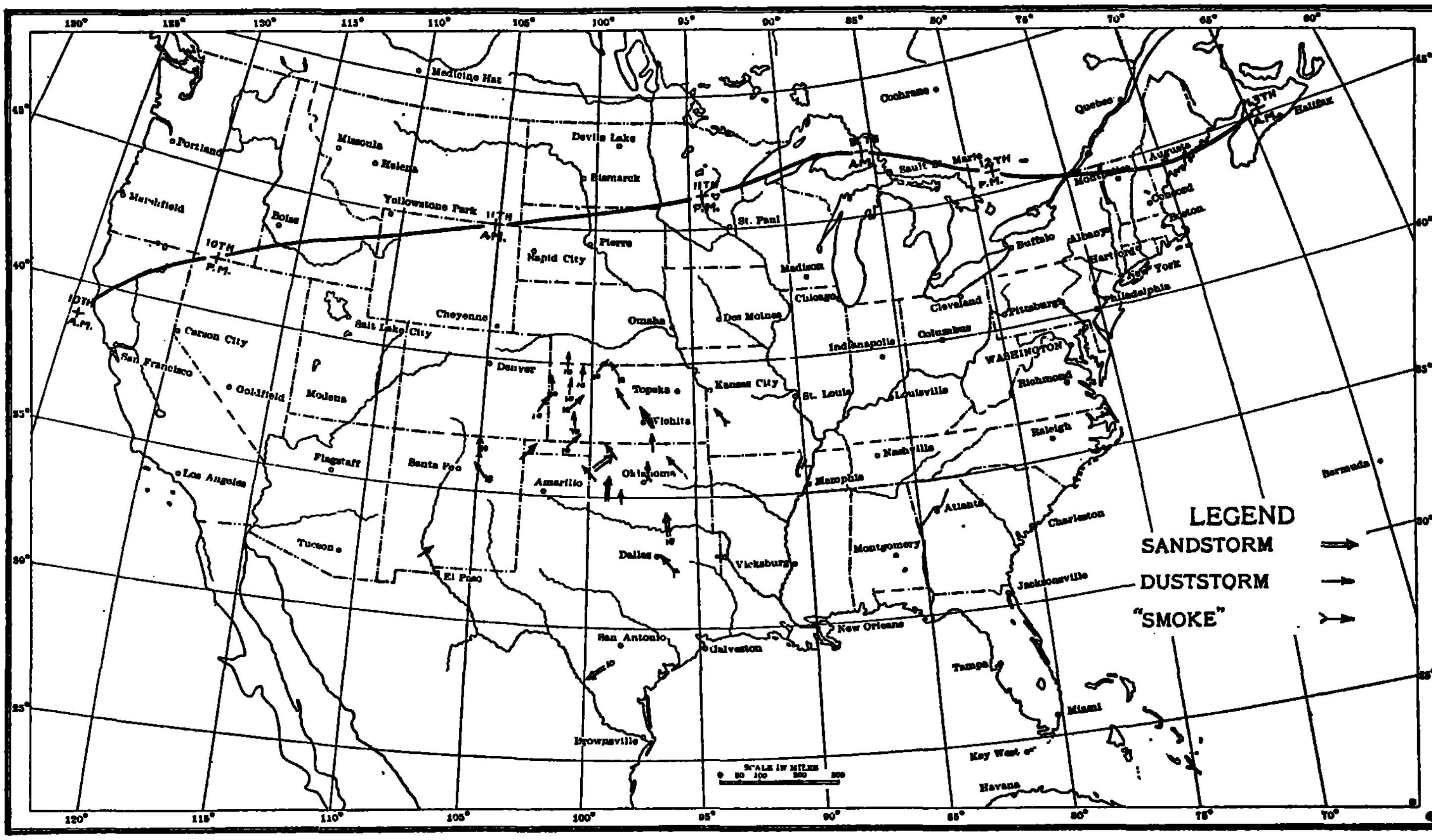

FIG. 2.—Dust of March 10 and 11, 1918: Cyclone track and dust storms reported by cooperative observers of the Weather Bureau in Arizona, New Mexico, Texas, Oklahoma, Kansas, and Missouri, March 10 (marked "10") and March 11, 1918.

(1) The winds near the ground can be eliminated at once, first because the dust was brought down at Madison by sleet, which from its form is known to have come from an upper, warmer stratum, and to have frozen in falling through a lower, colder stratum; and second, because the lower wind, traced back along its course is found to have come from the northeast, with only moderate velocity, over snow-covered ground and the waters of Lake Michigan, while it was under the influence of the storm, so that it had neither the strength nor the opportunity to pick up dust.

(2) We have attempted to compute graphically the trajectory of the upper, dust-bearing wind on the assump-

tion that it was a "gradient wind," and that the cyclone was of the "revolving fluid" type. The direction of a gradient wind is the direction of the isobar, its speed is determined by the pressure gradient, density of the air, deflective effect of the earth's rotation and centrifugal force due to a curved path. For our purpose this speed was determined by using the revised monogram recently published by Humphreys (**5**). Shaw (**8**) defines revolving fluid as "a column or disk of air which spins about a vertical axis and at the same time travels with a velocity of translation which is common to every part of the column or disk, and which therefore does not alter the relative motion of the air about its axis."

The gradient velocity was compounded with the average hourly drift of the storm. Working backward from Madison from the points determined by the observed beginning and ending of the dustfall, about 11 a. m. and velocity by 4 a. m. March 9. This example indicates that the calculated gradient velocity is a maximum condition, with respect to both northerly and easterly components of motion. It is scarcely probable that the true origin was as far west or as far north as the line of gradient velocity. On the other hand it is not likely that the place of origin of the dust was east of the 95th Meridian, because the strong convectional currents of daytime did not occur east of the Plains until the afternoon of the 9th, when the storm was passing over the Mississippi Valley. It was then too late for the fast, moving gradient wind itself must have reached the Mississippi River by 7 a. m. of the 9th in order to arrive at Madison by 11 a. m. That the nighttime ascent is weak, even in the center of the cyclone is strongly suggested by the daytime widening and nighttime narrowing of the belt of rain. The absence of rainfall about the center of the cyclone from midnight, March

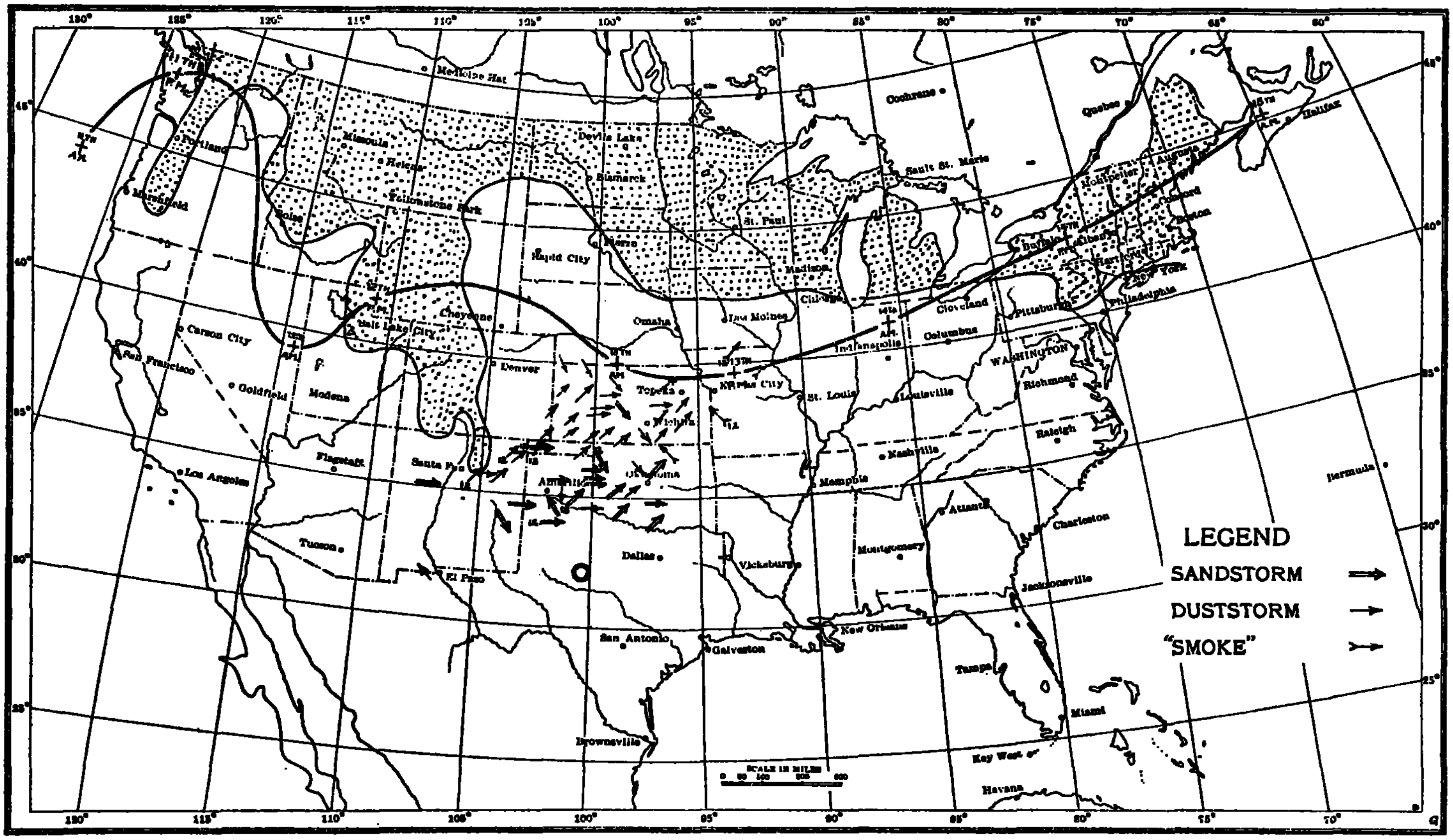

FIG. 3.—Dust of March 12 and 13, 1918: Cyclone track, snow-covered area (shaded), 8 p. m., March 11, 1918, and dust storms and sand storms reported by cooperative observers of the Weather Bureau in Arizona, New Mexico, Texas, Oklahoma, Kansas, and Missouri, March 12 (marked, "12") and March 13, 1918.

3 p. m., March 9, the trajectories marked A and B in figure 1 were obtained for the dust-bearing winds. These trajectories, and especially their loops, resemble the actual trajectories obtained by Shaw (**9**) from the study of surface air currents.

The dust must have been carried up from the ground, and while near the ground the dust-bearing currents must have been retarded by friction, and hence had then a smaller velocity, and a smaller deflection toward the isobar than is assumed for the upper winds. Curve D (fig. 1), represents the air current starting in northeastern Arizona at 4 p. m. with a velocity of 50 miles per hour (the observed maximum velocity at Flagstaff was 48). The direction is assumed at the begininng to be 45° to the left of the isobar. Increments of velocity of $2\frac{1}{2}$ miles per hour, and of deflection of $3\frac{3}{4}$° per hour are added each hour for 12 hours, bringing this wind up to the gradient 8, to noon, March 9, while it was advancing over Nebraska and Iowa, indicates exceedingly weak convection. Under these circumstances some of the dust-bearing wind could have made the circuit of the center without having its dust washed down by rain or snow.

Regions of deposition.—The fall of dust was not generally noticed by meteorological observers, so that we are not able to estimate the area covered or the total quantity of material that fell. In this respect conditions are very different from those of European falls, such as those of March 9–12, 1901, discussed by Hellmann and Meinardus (**2**), and of February 22, 1903, by Mill and Lempfert (**7**), for which many reports and measurements by both scientific men and the lay public were available.

By comparing the reports that were received, with the daily weather maps, it appears that cyclone III deposited dust at Madison, Portage, Hancock, Montello, and

Florence, Wis.; at Dubuque, Iowa; at Newberry in upper, and Grand Haven in lower Michigan, and at Chelsea, Vt. Rainfall of cyclone IV brought down dust at Columbus and Oberlin, Ohio, on March 12. The dust cloud accompanying this storm was observed at Tiffin, Wauseon, Pataskala, Plattsburg, Wilmington, and Oberlin, Ohio. In cyclone IV dust fell with snow at Woodstock, Vt., and with mixed sleet and rain at Alstead Center, N. H., on March 14.

Quantity of the dust.—At Madison the dust-bearing snow and sleet was collected from a measured square yard by Prof. W. H. Twenhofel. The quantity of dust obtained from this area amounted to 4 grams. For comparison this is converted to the usual units, in the following table, with the data given for European falls by Free (1).

Date.	Place.	Weight of dust.	
		Grams per square meter.	Tons per square mile.
Oct. 16, 1846	Southeastren France	0.63	1.8
Mar. 31, 1847	Tyrol	2.0	5.7
1859	Westphalia	30.0	85.8
February, 1862	Salzburg, Austria	0.08	0.24
Mar. 24, 1862	Carniola, Austria	5.0	14.3
Mar. 9-12, 1901	Various places in Europe	11.23-1.0	31.1-2.9
Mar. 19, 1901	Taormina, Italy	2.7	7.7
Mar. 9, 1918	Madison, Wis	4.8	13.5

Gross appearance of the dust.—At Madison, Wis., where the dust was mixed with a good deal of snow, it gave the latter a very light yellowish, or isabeau, tint. At Florence, Wis., "the snow was quite dusty in appearance, as to color a reddish brown;" Chelsea, Vt.—"it was noticed here as brown;" Alstead Center, N. H.—"was of reddish brown color;" Woodstock, Vt.—"snow was yellow and pink;" At Columbus, Ohio—"A peculiar reddish deposit was observed this morning on windows, and on white paint, where the rain of the morning had evaporated;" at Oberlin, Ohio—"produced a visible discoloration on the roofs." After the dust-laden snow began to thaw the surface became black at Madison, "rusty" at Newberry, Mich. The snow at Madison, melted for measurement, became black water, and would doubtless have been called "black rain" if it had fallen as rain.

Analysis of the dust.—The authors have reported elsewhere (10) the microscopic and physical analysis of the dust collected at Madison, so that only the following brief summary will be given here.

Microscopic study shows the dust to consist chiefly of minerals, but with some plant tissue, and a considerable number of diatom tests. The proportion of the chief constituents is estimated as follows:

Feldspar and quartz, 65 to 75 per cent.

Amorphous material, including limonite, hematite, kaolin, opal, etc., 20 to 30 per cent.

All other constituents about 5 per cent.

Microscopic measurements of the size of the particles show that they range from about 0.003 mm. to 0.1 mm., but a surprisingly large percentage falls within much narrower limits, namely 0.008 to 0.025 mm. Mechanical analysis of the dust, made by Prof. H. W. Stewart of the department of soils, University of Wisconsin, gives the percentage distribution shown in column No. 1 in the following table:

Size.	1	2	3	Size.	4	5
Mm.				*Mm.*		
0.005	11.15	17.8	11.3	0.004-0.008	1.5	
0.005-0.010	22.01			0.008-0.016	14.1	0.7
0.010-0.025	56.17	65.8	74.1	0.016-0.032	36.2	5.2
0.025-0.050	5.99			0.032-0.125	31.5	42.0
0.05-0.10	1.22	14.0	13.2	0.063-0.125	7.8	42.0
0.10-0.25	1.04	1.5	0.8	0.125-0.250	5.5	10.0
0.25-0.50	0.58	0.2	0.3	0.25-0.50	3.0	Tr.
0.5-1.0	0.29	1.0	0.2	0.5-1.0	0.2	
1.0-2.0	1.08	0.0	0.0	1.0-2.0		
	99.53	100.3	99.9		100.0	99.9

1. Dust from snow fall at Madison, Wis., Mar. 9, 1918.
2. Soil, Hays, Kans., which is subject to blowing. E. E. Free. "The Movement of Soil Material by the Wind, U. S. Bur. Soils, Bulletin 68, p. 168, 1911.
3. Silt loam soil ("Waukesha") from valley loess, Douglas County, Nebr., A. H. Meyer, et al., U. S. Bur. Soils, 15th Rept., p. 1994, 1913.
4. Dust from dust shower, Chicago, Ill., February, 1896. J. A. Udden, The Mechanical Composition of Wind Deposits, Augustana Libr. Pub. 1, p. 55, 1898.
5. Volcanic dust which fell on snow in Norway after a recent eruption in Iceland. J. A. Udden, l. c., p. 36.

For comparison similar analyses of soils, volcanic and atmospheric dusts are also given. This shows that the Madison dust is finer than the other dusts, and that a larger percentage of it is within a small range of sizes. Some soils contain much larger amounts of clayey material (0.005 mm.), but few contain as much silt (0.005 to 0.050 mm.); on the other hand, shower and volcanic dusts contain much less clay than the Madison dust. This may be due to the falling of shower and volcanic dusts wholly through the action of gravity, while the Madison dust was brought down, not by its own weight, but by the weight of the snow or rain condensed upon it.

A sample of dust collected by Prof. G. F. Wright at Oberlin, Ohio, on March 12, 1918, is strikingly similar to the dust that fell at Madison, consisting of the same minerals, the same spores and other organic fragments, and the same diatoms, although these seem to be decidedly rarer than in the dust that fell in Wisconsin.

The organic constituents of the Madison dust have been examined microscopically by Prof. R. H. Denniston of the department of botany of the University of Wisconsin, and he has been able to identify fragments of blades of grass, of leaves of clover or some similar legume, fibers of cotton, and of coniferous wood, all more or less decayed, and carrying saprophytic fungi and their spores.

Conclusion.—The importance of the wind in eroding and transporting soil material, in building soils, and in transporting spores of both useful and pathogenic organisms for long distances; and of the influence of atmospheric haze upon the absorbing and radiating power of the atmosphere, is so great that opportunity to collect quantitative data regarding them afforded by the observation of the phenomena of dustfalls should be taken advantage of by observers. Discolored snow and rain, from measured areas, such as that of the ordinary rain gage, should be evaporated, and the sediment forwarded to mineralogists or soil physicists for examination. The beginning and ending of the discolored precipitation should be specially recorded. It is also very desirable that fuller records of the haziness of the sky, red sun or moon, with the time of incidence, be made by meteorologists.

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SMOKE FROM MINNESOTA FOREST FIRES.

By HERBERT LYMAN.

[Dated: Weather Bureau, Washington, Jan. 2, 1919.]

A phenomenon of perhaps more than passing interest was witnessed from October 13 to 17, when smoke

FIG. 1.—Wind distribution, 8 a. m., Oct. 12, 1918.

clouds from the great forest fires of Minnesota and adjacent sections of Wisconsin rapidly spread over a large portion of the United States east of the Missouri River. These fires, of which there were no less than six[1] large ones, started on October 12, 1918, following a long period of exceptionally severe drought during which the precipitation had averaged only 20 to 25 per cent of the normal. To those interested in meteorology, however, the most interesting phase of the great fires is the remarkable rapidity with which the smoke traveled. Thus, in a little over 24 hours the smoke, borne by northwest winds, reached the Atlantic seaboard, and in another 24 hours had been carried as far south as Charleston, S. C.

To trace the development and course of the smoke cloud a series of charts (figs. 1 to 8) is presented. These were made up from the Washington daily weather maps and from the monthly reports of a number of regular and cooperative Weather Bureau stations within the area under discussion.

Figure 1 shows a moderate barometric disturbance along the northern border of Minnesota and Lake Superior on Saturday morning, October 12, only a few hours before the forest-fire smoke was first noticed. In Duluth, which was quite near the conflagrations, the weather was fine and clear in the morning. Shortly

FIG. 2.—Wind and smoke distribution, p. m., Oct. 12, 1918. "Sm"—light smoke; "Sm" in circle—dense smoke.

FIG. 3.—Wind and smoke distribution, a. m., Oct. 13, 1918. "Sm"—light smoke; "Sm." in a circle—dense smoke.

before noon smoke appeared in the west and became rapidly denser until 3 o clock when the sun was entirely obscured. By 4:30 p. m. the city lights had to be turned on. Figure 2, shows the cyclonic depression covering the entire Lake region with the center over Montreal. By the following morning, October 13 (fig. 3), this LOW had

[1] From a report to the U. S. Forest Service by National Forest Examiner John McLaren.